Influence of Low-Dose Protocols of CBCT on Dental Implant Planning

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Purpose: To evaluate the influence of low-dose protocols, with different numbers of basis images, on the precision of linear bone measurements in CBCT images. Materials and Methods: Five polyurethane mandibles, with different levels of bone resorption, were used in this in vitro study. To obtain the reference standard, landmarks were made in the mandibular superior and buccal cortices, and then a digital caliper was used to measure the bone height and thickness at these regions. CBCT images were obtained with the PaX-i3D (Vatech) unit set at 50 kV, 4 mA, 0.2-mm voxel size and 50 × 50-mm field of view. Keeping these parameters fixed, each mandible was scanned twice, with different protocols: Low dose (L) had an acquisition time of 24 seconds and 720 basis images, and ultralow dose (UL) had an acquisition time of 15 seconds and 450 basis images. Then, measurements of bone height and thickness were performed on the images, using the previously determined landmarks as reference. The obtained data were submitted to statistical analysis, with a significance level of .05. Analysis of variance, Student t test, and intraclass correlation coefficient were employed. Results: Regarding bone height, there were no significant differences between the measurements obtained with the L and UL protocols (P = .8648). Additionally, the L and UL protocols did not differ in relation to the reference standard (P = .8717 and P = .9928, respectively). Likewise, there were no significant differences between the measurements obtained with the L and UL protocols (P = .7965) for bone thickness, nor between these protocols and the gold standard (P = .7455). Conclusion: Considering the great demand for precise measurements in implantology, protocols of low-dose radiation can be used without compromising clinical planning. Int J Oral Maxillofac Implants 2021;36:307–312. doi: 10.11607/jomi.8773

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Radiographic images are commonly used for diagnosis and treatment planning in implantology, although they provide only two-dimensional representations of three-dimensional structures. In order to overcome the limitations inherent to radiographs, CBCT can be used, as it allows a three-dimensional visualization of the object under study. However, this type of exam requires higher radiation doses compared with two-dimensional images.1–3

The CBCT devices operate at higher energy parameters than the equipment used to obtain radiographic images. CBCT units work by directing the pyramidal or conical x-ray beam through the patient’s head to a flat panel or image intensifier detector, acquiring a series of basis images that are reconstructed by mathematical algorithms to generate sets of volumetric data. Then, these data are processed by software to provide multiplanar reconstructions and transversal, sequential, and contiguous projections of the scanned structures.2–4

The number of basis images available for volume reconstruction is directly related to the radiation dose to which patients will be exposed, and in most CBCT units, it is determined by the scanning time and/or by the device’s rotation degree. When the other acquisition parameters are kept fixed, the longer the time for image acquisition, the greater the number of basis images and information to reconstruct the volumes, but also the higher the radiation dose. Partial rotation (180 degrees) of the device, compared with full rotation (360 degrees), is performed with a shorter exposure time, lower number of basis images, and consequently, a lower radiation dose. Although technologic development has

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allowed a significant reduction in radiation doses, there is still a constant concern about the radiation emitted by imaging exams using ionizing radiation. Therefore, reducing the radiation dose must be considered whenever possible.5–7

When the energetic parameters are kept fixed, image acquisitions with shorter exposure time and/or lower rotation degree of the device are considered low-dose protocols; nonetheless, these protocols generate a low number of basis images. The number of basis images is associated with the amount of information available to reconstruct the tomographic volume, and consequently, with the quality of the CBCT images.8 Fidelity in the representation of bone structures and precision in linear measurements are crucial for preoperative planning of implants, especially when applied to image-guided implant surgery. All guided surgery systems show some degree of imprecision, resulting in horizontal and, particularly, vertical deviations of the implant position compared with the presurgical virtual position.9 Thus, for dental implant planning, in theory, it would be necessary to acquire basis images in a sufficient amount to ensure image quality and adequate evaluations.

Bearing in mind the importance of using protocols of low-dose radiation while maintaining sufficient image quality for diagnosis, the aim of the present study was to evaluate the influence of low-dose protocols, with varying numbers of basis images, on the precision of linear bone measurements in CBCT scans.

MATERIALS AND METHODS

This was an experimental, in vitro, analytical, controlled, accuracy study.

Sample Preparation

Five synthetic mandibles made of polyurethane, with a density similar to that of bone tissue, were used in the present study (Nacional Ossos; Fig 1). The mandibles were edentulous and had different levels of alveolar bone resorption to simulate different clinical conditions. The region between the mental foramina corresponded to the evaluated area, considering the planning of an implant-supported mandibular denture.
To enable the measurements in the CBCT images, eight perforations were made in the interforamina region of each mandible to obtain reference landmarks (Fig 2). Four perforations were made in different points of the alveolar ridge to determine the distance from these landmarks to the mandibular base (height measurement), and four other perforations were made in different regions of the buccal cortex to determine the distance from these points to the lingual cortex of the mandible (thickness measurement). Perforations were performed with a carbide spherical drill (no. ½; KG Sorensen) and a low-speed handpiece. The depth of the perforations corresponded to the drill diameter.

Reference Standard
A digital caliper (Starrett no. 727-6/150), which was previously calibrated and adapted for this study, was used to measure the mandibular heights and thicknesses. For the bone heights, measurements were performed from the perforations in the alveolar ridge to the mandibular base, following the inclination/long axis of the mandible. Perforations were made with a carbide spherical drill (no. ½; KG Sorensen) and a low-speed handpiece. The depth of the perforations corresponded to the drill diameter.

Image Acquisition
CBCT images were acquired with the PaX-i3D (Vatech) unit set at 50 kV, 4 mA, 0.2-mm voxel size and 50 × 50-mm field of view (FOV). Keeping these parameters fixed, each mandible was scanned twice, with different protocols (Fig 3): low dose (L)—acquisition time of 24 seconds and 720 basis images; and ultralow dose (UL)—acquisition time of 15 seconds and 450 basis images.

Image Evaluation
Images were evaluated by one previously calibrated examiner (H.S.C.), with experience in the evaluation of CBCT images, using the CS 3D Imaging Software (Carestream Dental). The measurements were performed with the aid of the linear measurement tool of the software. In reconstructions that transverse to the center of the perforations in the alveolar ridge, measurements of bone height were performed from the deepest point of the perforations to the mandibular base, following the inclination/long axis of the mandible; bone thickness measurements were performed from the deepest point of the buccal perforations to the lingual cortex of the mandible, parallel to the horizontal plane (Fig 4).

All evaluations were performed in a silent and dimmed-light environment. Manipulation of image brightness, contrast, and zoom was allowed.

Statistical Analysis
The data were submitted to statistical analysis, with a significance level set at .05. The analysis of variance (one-way ANOVA) compared the measurements obtained for
Regarding the biologic effects of the ionizing radiation used in dental exams, it is well-known that there is a real risk for the manifestation of stochastic effects, without a safe threshold, and the development of mutations and cancer.\textsuperscript{10–13} Therefore, for any image modality, the radiation dose must be as low as reasonably achievable, as stated in the ALARA principle of radiation protection.\textsuperscript{5} However, considering the need for imaging exams to fulfill their role as a complementary diagnostic tool, not only must the radiation dose be as low as possible, but the image quality must be adequate for diagnosis, as recently recommended by the ALADA principle (as low as diagnostically acceptable).\textsuperscript{5} Hence, several studies have been carried out to establish protocols of low-dose radiation and acceptable image quality.\textsuperscript{14,15}

Although CBCT requires higher radiation doses compared with other imaging modalities in oral diagnosis, it is an essential tool for the three-dimensional evaluation of craniofacial bones. CBCT images allow evaluation of the height and thickness of implant sites, as well as their relationship with the adjacent structures, which cannot be done by means of radiographic images.\textsuperscript{5,16}

In the present study, the measurements of bone height and thickness were performed in the anterior region of the mandible, in the area between the mental foramina, as the placement of implants was considered for rehabilitation with a mandibular prosthesis in a fully edentulous patient. The anterior region of the mandible, instead of the posterior region, is often chosen for this type of rehabilitation due to a lower risk of injury to vasculo-nervous structures.

Previous authors have reported that CBCT images acquired with partial or full rotation of the device produce similar precision in the assessment of different diagnostic tasks. Therefore, they recommend the use of 180-degree rotation, due to the reduction in the radiation dose to the patient and consequent decrease in biologic risk.\textsuperscript{9,17–20} In view of the importance of CBCT images for implantology, it is necessary to study the possibility of employing low-dose protocols and obtaining images of acceptable quality for diagnosis, evaluating the accuracy of bone height and thickness measurements for dental implant planning. However, only few devices offer the possibility to choose between full or partial rotation. Nevertheless, newer equipment enables the adjustment of other image acquisition parameters in order to reduce the radiation dose, such as number of basis images, exposure time, and/or speed of rotation of the device, without changing the degree of rotation. Therefore, it becomes important to assess the influence of the dose reduction obtained through alterations in these parameters on diagnosis.

Considering the radiation dose to which the patient will be exposed, the UL protocol used in this study

### RESULTS

Table 1 shows the reference standard (RS) measurements and the measurements obtained from the CBCT images for both L and UL protocols.

There were no significant differences for the measurements of bone height (\(P = .9986\)) and thickness (\(P = .7764\)), when the three groups were compared. Regarding the measurement of bone height, the L and UL protocols did not differ significantly from the reference standard, with \(P\) values of .8717 and .9928, respectively. Additionally, there was no significant difference between the measurements obtained with the L and UL protocols (\(P = .8648\)).

Likewise, the measurements of bone thickness did not differ significantly from the reference standard, with a \(P\) value of .7455 for the L protocol and a \(P\) value of .9465 for the UL protocol. There was no significant difference between the measurements obtained with the L and UL protocols as well (\(P = .7969\)).

ICC demonstrated excellent intraexaminer agreement (ICC = 0.9878) for the measurements performed in the CBCT images.

### DISCUSSION

An increase in the radiation exposure time for CBCT acquisition, when the other parameters are kept fixed, will result in a greater number of basis images and, therefore, in a greater amount of information available to reconstruct the tomographic volume; on the other hand, the radiation dose to the patient will be higher.\textsuperscript{2}

## Table 1 Mean and SD Values (mm) of Bone Height and Thickness for the Reference Standard and L and UL Protocols

<table>
<thead>
<tr>
<th></th>
<th>RS</th>
<th>L</th>
<th>UL</th>
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<tbody>
<tr>
<td>Bone height</td>
<td>16.27 (± 6.3)</td>
<td>16.49 (± 6.42)</td>
<td>16.43 (± 6.48)</td>
</tr>
<tr>
<td>Bone thickness</td>
<td>10.6 (± 2.4)</td>
<td>10.98 (± 2.29)</td>
<td>11.12 (± 2.48)</td>
</tr>
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\(RS = \) reference standard; \(L = \) low dose; \(UL = \) ultralow dose.
would be equivalent to a partial rotation protocol. UL and partial rotation are protocols that emit lower doses of radiation to the patient. In such cases, a lower number of basis images are obtained, and the time for image acquisition is shorter. However, it is important to highlight that, in the present study, although the image acquisitions were performed with a shorter exposure time, lower radiation dose, and lower number of basis images, there was no alteration in the equipment’s rotation degree.

The effect of partial (180-degree) and full (360-degree) rotations on the image quality has been studied in implantology, but only for bone height evaluation in orthodontics, for the evaluation of bone sites for mini-implant placement; in endodontics, for diagnosis of periapical lesions; and in the analysis of bone thickness. All these previous studies reported that the images obtained with partial rotation of the CBCT device were satisfactory for the diagnostic task proposed. Likewise, there were no differences in the precision of bone height and thickness measurements between the images obtained with the UL and L protocols in the present study.

Hassan et al evaluated the influence of rotation degree on the visibility of root canals in CBCT images. The authors found a negative influence of partial rotation in comparison to full rotation. This finding may be associated with the diagnostic task assessed, since the evaluation of root canals is more detailed and challenging than measurements of bone height and thickness, for example.

Costa et al observed that, for images obtained with smaller FOV sizes, the acquisition with full rotation resulted in reduction of image noise. However, this reduction may be more related to the FOV size than to the number of basis images, since Queiroz et al found that there is no significant difference in noise production among images obtained with different numbers of basis images; ie, protocols of lower exposure time did not compromise the image quality.

Another important factor about low-dose protocols is the obtention of images with a shorter time, compared with other protocols. Spin-Neto et al studied the patient’s movement as a limiting factor for image quality. In low-dose protocols, such as UL, the CBCT gantry rotates around the patient with shorter exposure time. The shorter the exposure time, the lower the chance of patient movement, minimizing the possible need to repeat the exam. Thus, protocols of shorter exposure time or partial rotation, besides enabling lower doses of radiation to the patient and faster image acquisition, also provide faster image reconstruction due to the lower number of basis images, without impairing diagnostic accuracy.

It is important to consider that the present study had an in vitro design, and was developed using synthetic mandibles, as performed in the study by Benic et al. In order to maintain the clinical representativeness, the present study opted to use mandibles made of polyurethane, as this material presents a density similar to that of bone tissue. Although there are inherent limitations to this type of study, it is necessary to consider the importance of this approach as a way of isolating variables so that there is no influence from external factors.

CONCLUSIONS

Bearing in mind the great demand for precise measurements of bone height and thickness in implantology, low-dose radiation protocols can be used without compromising clinical planning.

ACKNOWLEDGMENTS

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